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COMMAND AND CONTROL, CYBER, COMMUNICATIONS, INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE (CRISR) AND CYBER TACTICAL MEASURES

GEORGIA TECH RESEARCH INSTITUTE (GTRI)
CYBER TECHNOLOGY AND INFORMATION SECURITY LABORATORY (CTISL)

SEPTEMBER 2016

FINAL TECHNICAL REPORT

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14. ABSTRACT

The objective of this effort was to research and document gaps in National Security and identify potential solutions. Scientific and technical information regarding current capabilities, gaps and vulnerabilities were explored to counter adversarial Command and Control, Cyber, Communications, Intelligence, Surveillance and Reconnaissance (C4ISR) capabilities. The research addressed a number of areas of high interest affecting National Security. This effort provided scientific and technical information by researching capability gaps within current government solutions, identifying vulnerabilities and weighing solutions for new gaps. The effort determined the alternatives, identified associated risks, and provided potential solutions in various technical areas such as C4ISR and other related technologies. Rapidly evolving technology developments from both commercial and military sources have the potential to enable new National Security capabilities that may not be envisioned in current AF strategic master plans. In addition, these plans typically do not provide sufficient metrics for technology investment decisions. The National Security C45ISR and Cyber Tactical Measure project researched innovative solutions of evolving technology developments from both commercial and military sources, and identified new useful technology supporting S&T.

15. SUBJECT TERMS

D-Wave, Commercialization, Quantum Computing, Technology Transfer, Defense Innovation Unit Experimental

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1 SUMMARY

The views documented in this report do not necessarily reflect those of AFRL, but those of SMEs asked to brainstorm specific topics covered in this report. The National Security Command and Control, Cyber, Communications, Intelligence, Surveillance and Reconnaissance (C4ISR) and Cyber Tactical Measures project researched innovative solutions of evolving technology developments from both commercial and military sources, and identified new useful technology supporting Science and Technology (S&T).

This project completed four meetings, about one per quarter, with the senior leaders guiding discussions on critical topics of concern to AFRL and the DoD. Each session was 8-hours with interactive guided discussion on topics researched prior to the session.

1.1 Meeting #1 topics: Overarching theme (World Class Laboratory)

- Technology Watch & Horizon Scanning
- Jointness
- Becoming a World-Class Laboratory
- Becoming a Laboratory Hub
- Metrics

1.2 Meeting #2 topics: Overarching theme (Commercialization)

- Vision for Commercialization
- DoD Technology Transfer (T2) Program Long Term Goals/DHS Transition to Practice Program
- DoD-Economic Impacts Review
- Rules that Facilitate DoD Commercialization & Partnerships?
  - Who is Doing This Well?
  - How Do They Do It?
- What are the Opportunities?
- What is Inside & Outside of AFRL's Control, Key Enablers

1.3 Meeting #3 topics: SME Immersion—held in Rome, NY

- Senior leaders topics
  - Autonomy, C2, and Decision Support
  - Connectivity and Dissemination o Cyber Science and Technology o Processing & Exploitation
- Cyber Protection Innovation Cell proposal
- "Internet of Things" (IoT) impacts on the DoD
- D-Wave quick look review

1.4 Meeting #4 topics: Overarching theme (Speeding Technology to the Warfighter)

- Discuss Defense Innovation Unit Experimental (DIUx)

- Silicon Valley Trip Report
- DoD-Cultural Barriers
- Corporate Board Insights
- West Coast Perspective
- Chertoff Perspective

After completing the four meetings, the funding was expensed and the project was not funded further.

2 INTRODUCTION

The objective of this effort was to research and document gaps in National Security and potential solutions. Scientific and technical information regarding current capabilities, gaps and vulnerabilities were explored to counter adversarial C4ISR capabilities.

The key was to help develop a portfolio of technologies to support evolving warfighter requirements for C4ISR. Moreover, as DoD trends toward Joint and Coalition operations with the shift in emphasis from Iraq and Afghanistan to Anti-access Area Denial (A2AD), Africa (and other conflicts) makes it essential that lessons learned from past operations be rapidly and effectively translated into new technology development to advocate emerging war fighter and other National Security needs. This is critical to identifying potential material and non-material solutions to Air Force capability gaps while using previous best practices. In the current environment of sequestrations and diminishing budgets, it is imperative that the Information Directorate addresses the most critical and highest payoff S&T.

There were two phases established, each solving a specific government requirement within this contract.

The first phase was to conduct and document research on emerging threats affecting National Security in the areas of Cyber security and C4ISR. Specifically, this phase involved researching potential innovative solutions and evolving technology developments from both commercial and military sources, and identifying new useful technology supporting S&T. Further, this project focused on identifying potential technologies in an architectural and operational framework to quantify enabling National Security capabilities.

The second phase, (not funded), was to complete a technical analysis on Cyber, Communications and Embedded Computing researching technology best practices and emerging technology requirements to define Cyber Communications and Embedded Computing challenges and concepts. Further analysis was to identify synergistic solutions from Academia, Industry and Government sources, and document potential solutions to current gaps in blue capabilities.

3 METHODS, ASSUMPTIONS, AND PROCEDURES

3.1 Special Tasks/Current Status

As specified in the SOW, during Phase I, GTRI conducted and documented research on emerging threats affecting National Security in the areas of Cyber security and C4ISR. GTRI researched innovative solutions of evolving technology developments from both commercial and military sources, and identified new useful technology supporting S&T. GTRI identified potential technologies in an architectural and operational framework to quantify enabling National Security capabilities.

Phase I: Required the following preparation from the high-level Subject Matter Experts (SMEs).

- Help provide C4I & Cyber S&T strategic direction (guide decisions and insight)
- Help provide insight into better ways to improve the technical program plan
- Provide insightful research and also champion direction

To perform the Phase I task, GTRI subcontracted four high-level subject matter experts to conduct research as stated above and provide recommended solutions.

The following paragraphs summarize each of the Meetings and provide an overview of several of the topics that were worked as pre-Meeting preparation and post-Meeting actions items.

3.2 Results and Discussions from Meeting #1:

GTRI SMEs led discussions to address a broad set of topics. Each topic was reviewed amongst the SME's via telecon prior to the meeting to focus a direction for the actual meeting. The below are the first meeting topics.

3.2.1 Emerging Near-Peer Considerations.

There were two thoughts proposed during this discussion period…"Future Operational Environment" and "Restoring Airmindedness to the Air Force".

3.2.1.1 Future Operational Environment

Trends in the operating environment which challenge opposed access for U.S. joint forces:

- The dramatic improvement and proliferation of weapons and other technologies capable of denying access to or freedom of action within an operational area,
- The changing U.S. overseas defense posture (decreased support for overseas bases, declining resources, difficulty protecting US forces), and
- The emergence of space and cyberspace as increasingly important and contested domains.

Key anti-access capabilities of potential adversaries include:

- A variety of surface-, air- and submarine-launched ballistic and cruise missiles able to accurately attack forward bases and deploying U.S. forces and their supporting logistics at ranges exceeding 1,000 nautical miles.
- Long-range reconnaissance and surveillance systems that provide necessary targeting information, including satellites, aircraft, and land and ship-based radar.
- Kinetic and non-kinetic antisatellite weapons that can disable space systems vital to U.S. force projection.
- Submarine forces able to interdict U.S. and friendly sea lines of communications in both sovereign and international waters between U.S. bases and the theater of operations.
- Cyber Attack capabilities designed to disrupt U.S. command and control systems and critical infrastructure, both civilian and military.
- Terrorists willing to attack U.S. or partner bases and deploying forces, even at points of origin in the continental United States or other regions.
- Special operations forces capable of direct action and unconventional warfare in the approaches to the operational area.

Key area-denial capabilities include:

- Air forces and air defense systems, both fixed and mobile, designed to deny local U.S. air superiority.
- Shorter-range anti-ship missiles and submarines employing advanced torpedoes to deny

U.S. maritime superiority in the objective area.

- Precision-guided rockets, artillery, missiles, and mortars (G-RAMM) designed to attack surface targets, including landing forces, with much greater accuracy and lethality than their dumb weapon predecessors.
- Chemical and biological weapons to deny the use of select areas.
- Computer and electronic attack capabilities to degrade, neutralize, or destroy U.S. command and control in the operational area.
- Abundant land and naval mines capable of quickly closing straits, land passes, long stretches of coastline, or airfields.
- Armed and explosives-laden small boats and craft in cluttered and restricted coastal waters and straits.
- Well-equipped land maneuver forces.
- Special operations forces capable of direct action and unconventional warfare in the objective area.
- Unmanned systems, such as unmanned aircraft and unmanned underwater vehicles, which could loiter to provide intelligence collection or fires in the objective area.

Air-Sea Battle: Air-Sea Battle's purpose is to enhance cooperation within the Department of the Air Force and the Department of the Navy. Air-Sea Battle is a "limited operational concept" that focuses on the development of integrated air and naval forces in the context of anti-access/area-denial threats. There are three components:

- The first component is an institutional commitment to developing an enduring organizational model that ensures formal collaboration to address the anti-access/area- denial challenge over time.
- The second component is conceptual alignment to ensure that capabilities are integrated properly between Services.
- The final component is doctrinal, organizational, training, materiel, leadership and education, personnel, and facilities initiatives developed Jointly to ensure they are complementary where appropriate, redundant when mandated by capacity requirements, fully interoperable, and fielded with integrated acquisition strategies that seek efficiencies where they can be achieved.

3.2.1.2 Restoring Airmindedness to the Air Force

Can the Air Force apply the Airman's perspective to suggest alternative approaches to other issues facing the Nation today? Clearly it can—and we must. Airmen look at problems differently; thus, finding alternatives may require that it restate the problems the Nation or Joint Force commanders are attempting to resolve. Some of the most useful answers could come from the community which strives to achieve national objectives by using military force to avoid combat. Additionally, as the Air Force examines its priorities and mission following recent events that involved bombers and ICBMs, it must decide whether these were isolated occurrences restricted to the nuclear operations community or events symptomatic of an overall loss of focus on why the Air Force is important. The international political environment has changed, but a quick review of recent military and national security operations suggests that the Nation needs the US Air Force for the same reasons it was established in 1947:

- to sustain a full-spectrum force that encourages innovation, stimulates science and technology, and strengthens partners across the globe;
- to offer alternatives to force-on-force conflict by developing strategies based on operating interdependently with other US and partner instruments of power;
- to provide alternative Joint courses of action that reduce the risk of US and friendly-force casualties when operating as an interdependent Joint and coalition force; and
- to support ground commanders with the world's best air surveillance, close air support, and other supporting tactical capabilities.

As we consider the role of the Air Force in the future, we clearly see that, from its beginnings, the Air Force has postured itself to protect America's homeland and citizens from attack, to help assure our allies and partners, and to contribute to the advancement of America's global interests. It does this using airlift, long-range strike (employing both aerial tankers and attack platforms), surveillance and reconnaissance, force enhancement from space, and other capabilities inherent to air forces. To put this in clear terms that apply to all Airmen regardless of their functional specialty, Airmen protect the Nation and its global interests by conducting global, regional, and tactical

operations through air, space, and cyberspace. Looking ahead, to best leverage the US Air Force, the Nation should encourage Airmen to look at national security through the strategic lens that made the Service so valuable in the past, and the Air Force must foster a culture where Airmen feel a sense of professional pride when performing the Air Force's "power for peace" mission.

Trends in the operating environment which challenge opposed access for U.S. joint forces:

- The dramatic improvement and proliferation of weapons and other technologies capable of denying access to or freedom of action within an operational area,
- The changing U.S. overseas defense posture (decreased support for overseas bases, declining resources, difficulty protecting US forces), and
- The emergence of space and cyberspace as increasingly important and contested domains.

3.2.2 Strategic Partnerships/Non-traditional Paths and Laboratory Hubs

Research and discussion addressed partnerships to enhance S&T efforts and what non-traditional paths could be leveraged to enable its S&T objectives. Research and discussion also addressed considerations to become a laboratory hub for OSD, DHS and/or the IC.

A significant focus on information technology may make it difficult to successfully transition **ED**technology consistent with the intent of federal policy and guidance. Most research in information technology is being pushed by commercial companies driven to capture expanding global market share. These firms drive innovation and change in their commercial products at a pace faster than the federal government. Most Federal agencies, including the Department of Defense, are primarily focused on how to best use this technology and take advantage of the opportunity it provides.

3.2.3 Jointness

Should AF Laboratories be striving to be more Joint? In what ways or what research areas? (Rephrased: Should labs focus exclusively on Air Force ops, or "air-minded" Joint ops which might require developing capabilities for other Services, Agencies, and international partners. What are the other Service labs doing in C4ISR and where does it make sense to partner?) What does it take to be a world-class laboratory? (Rephrased:

> What are the top five laboratories (regardless of sector) in the world, and why are they considered among the top 5?) What metrics should be utilized? (Analogy: Do we compare Coke sales to Pepsi products, or to worldwide consumption of drinking water?)

Background, observations and potential implications regarding focusing on Joint, AF and air-minded Joint operations:

> "Joint" may not be the most relevant term. The term traditionally refers to the integration of unique or specialized military Service capabilities to enhance

operational effectiveness, after development. The intent above, it may be more compelling to focus on where the research and expertise is either: 1) unique and therefore singularly compelling, 2) universally applicable to multiple Service, Agency and Department missions (gaps), 3) united to a single mission (AF?) core competency and interest or 4) requires significantly less resources or up front capital for implementation than others' alternatives. This delineation could be the focus for all initiatives or a specified distinction for each R&D initiative. It is a focus on expertise and innovative capability up front, rather than a narrowing based on predetermined mission parameters…i.e. realm of the possible in application of truly unique emerging capabilities. Convergence? Integration? Invented vs leveraged?

3.2.4 Being a World-class Laboratory

Research and discussion addressed what it takes to be a world-class laboratory. How successful is the DoD R&E?

- FY2009: 690 Patent Applications
  - Assume $15K/patent then the cost ~ $10.35M/year
- FY2009 License Income: $16.165M
  - Excluding Uniformed Services University of the Health Sciences (USUHS) it was ~$6M Excluding the FTE costs – DoD is likely not even covering the cost of patents
- Submitting more patent applications without fundamentally changing the ecosystem for commercialization within DoD will only increase costs without commensurate revenue
  - Dr. John Fischer DRAFT Memo (October 2014) identified the following Technology Transfer Program Long-Term Goals:
    - Creation of a Technology Transfer (T2) Professional Certification and Warranting
    - Establishment of a Department-wide pool of Patent Attorneys
    - Pooling of DOD Laboratory Intellectual Property within the DoD and with other Federal Government Agencies
    - Improve the availability and marketability of DoD Lab Intellectual Property [i.e., a web site]
    - Standardized business interface and agreements with DoD Labs

Commentary: Tech Transfer is a “contact sport” with required heavy lifting by the inventor (or organization) to identify potential applications, markets, and licensee – the above goals do not really move the ball down the field.

3.2.5 Tech Transition and Commercialization

Research and discussion addressed ways to pursue transitioning technologies and what commercialization means to a DoD laboratory considering commercialization efforts of most academia and other research institutes have not historically yielded large financial returns on investment. Why Commercialize?

- In decreasing order of importance (and likelihood):
  - Speed transition to warfighter
  - Change culture / create incentives for the staff
  - Gain insight on the R&D direction of the private sector
  - Political support (if done right – jobs, tech. insertion, …)
  - Possible discretionary funds

Note: motivation for universities to have tech transfer offices: Bayh-Dole requires reporting and Wadey v. Duke (2002) significantly narrowed the research exclusion provision

- Investments are tied to perceived risk. DoD is often risk-adverse (for good reason). Other markets can reduce the risk of manufacturability, reliability, etc. and speed the adoption for DoD.
- Transitioning to other industries can reduce the perceived risk – and hence accelerate the adoption of new technologies in DoD. Early adopters can prove out the "ilities" (reliability, manufacturability, affordability, etc.) and DoD can leverage.
- Considerations when Commercializing
  - Communication Strategy – w/employees to stay focused on mission (big risk); DoD & Congress to set expectations, …
  - Need for a sophisticated IP strategy on internal research and fostering good behavior to avoid conflicts with performers
  - Accounting and use of government IP rights
  - Export – think about dual use up front
  - Exclusive vs. non-exclusive rights to speed transition
  - License / JDA / start-up – how to do "comps" and defend the terms & conditions to critics
  - Speed, speed, speed – no commercial entity wants to operate at government timescales… especially VCs and start-ups
  - How to mesh VC culture (and expectations) with government bureaucracy
  - How to gain "intel" from commercial side on future developments that can affect strategy (creating a virtuous cycle)

3.2.6 Conclusions from the Topic of "Becoming a World-Class Lab"

- It isn't the technology, but rather the business model applied with the technology that makes the difference.
- In its "Design" role, a World Class Lab should be a fast follower / early adopter. Meaning the lab must be plugged into the customer to be effective.
  - Co-development (e.g., with the end user) is key for a World-Class Lab and requires access to the end user & you structure yourself differently.

3.2.7 Conclusions from the Topic of "Why Commercialize?"

- In decreasing order of importance (and likelihood):
  - Speed transition to warfighter
  - Change culture / create incentives for the staff
  - Gain insight on the R&D direction of the private sector o Political support (if done right – jobs, tech. insertion, …) o Possible discretionary funds
  - Commercialization won't be a significant money maker
  - When to Commercialize? When it speeds the transition to the warfighter

3.2.8 Conclusions in "The Operating Environment"

- Emergence of space and cyberspace as increasingly important in contested domains.
- Cyber Attack capabilities designed to disrupt U.S. command and control systems and critical infrastructure, both civilian and military.
- Computer and electronic attack capabilities to degrade, neutralize, or destroy U.S. command and control in the operational area.
- Unmanned systems, such as unmanned aircraft and unmanned underwater vehicles, which could loiter to provide intelligence collection or fires in the objective area.

3.2.9 Conclusions from the Topic of "Striving to be More Joint?"

Rephrased: Should AF Laboratories be focused exclusively on Air Force ops, or "air-minded" joint ops which might require developing capabilities for other services, agencies, and international partners.

- The answer should reflect whether AF Labs believe their best focus is strictly AF, all Service, Agency/Department-wide, or heavily partnered with academia and commercial industry.
- Should AF Labs be focused on helping customers see new possibilities, or focus on known gaps and problems? The latter is currently prevalent in prepared materials.
- A potential model for partnering or "Joint" focus may be the expertise to partner with the key inventor (National Lab, Industry, academia and do the leveraging R&D required for specialized implementation in air, sea, space, intelligence or C2 operations).
- Consider partnering with US Coast Guard (as component to USCYBERCOM) as alternative to engage DHS and law enforcement entities?
- Combatant Command processes and influence are directly moving new capabilities and funding streams. The nuances of mission focus and resourcing processes, as well as Service/Agency/Law Enforcement/Guard and other partnership implications for TRANSCOM, STRATCOM, SOCOM, PACOM and NORTHCOM are worth consideration.
- High NGB/ANG interest in cyber and ISR missions relative to Service Components, as well as direct State, Gubernatorial and Homeland Defense initiatives.
- AF Labs could be the "integration" or convergence expert-- developing specific case studies for STRATCOM, CENTCOM and PACOM mission sets as an entry opportunity for new technologies.

3.3 Results and Discussions from Meeting #2:

GTRI SMEs led discussions to address a broad set of select topics. Each topic was review amongst the SME's via telecon prior to the meeting to focus a direction for the actual meeting. The below are the second meeting topics.

3.3.1 DoD's Technology Transfer (T2) Goals

This topic was set-up as an open, thought leader discussion. DHS provided perspective on DoD Tech Transfer and addressed topics contained in Dr. John Fischer's, ASD(R&E), long-term goals for DoD commercialization. Addressed were the creation of a T2 professional certification and warranting program, establishing a Department-wide pool of patent attorneys, pooling intellectual property within the DoD and Federal Agencies, improving the availability and marketability of DoD intellectual property and a standardized business interface and agreement with DoD Labs. There are five goals set forth by ASD(R&E).

- **Creation of a Technology Transfer (T2) Professional Certification and Warranting Program.** Akin to the requirements for Contracting Officers established by the DoD and Components, this program would mandate personnel serving in the Offices of Research and Technology Applications (ORTA) be certified and warranted for their positions. An advanced training and educational degree program (i.e., MBA) would be created and offered to ORTAs to meet the new requirements. Upon fulfilling the training, education and experience needed for certification and warranting, ORTAs would be authorized to execute all of the duties associated with their offices without additional oversight or approval.
- **Establishment of a Department-wide pool of Patent Attorneys.** The largest single impediment to the generation of patents within the DoD laboratory community is a shortage of Patent Attorneys. Establishing a contractual relationship with a pool of Patent Attorneys which would be accessible by all laboratories should ease the burden on existing legal support teams at labs and offer a surge capability to ensure timely filing of intellectual property claims.
- **Pooling of DoD Laboratory Intellectual Property within the DoD and with other Federal Government Agencies.** Single patents seldom attract the attention of the commercial marketplace. As technology based systems increase in complexity, grouping of pieces of intellectual property are required to develop a useable product with monetary value. To this end, creating the ability to analyze the entire DoD Lab IP portfolio to group or pool patents by technology system and subsequent marketing of the bundled patents to commercial businesses for licensing would increase the impact of the DoD Lab T2 program. Concurrently, examine the potential of bundling DoD Lab IP with the IP available in other Federal Laboratories for an even greater impact in the commercial marketplace.
- **Improve the availability and marketability of DoD Lab Intellectual Property.** Accessibility of DoD Laboratory IP can be challenging commercial businesses, especially small businesses. Navigating the existing DoD Lab IP portfolio is difficult if not a subject matter expert in narrow fields of expertise or knowledgeable of government business practices. There is a need to create a simple, understandable, facile and readily available "one-stop-shop" of DoD Lab IP. This location, most likely a well- advertised

web-site would offer an easy to navigate interface allowing the business world with a quick overview of available DoD lab IP, how to communicate with relevant points of contact and details of how to proceed to next steps. Concurrent to this, there is a need to market available IP to private sector companies who may not be aware of the plethora of marketable technologies available for licensing.

- **Standardized business interface and agreements with DoD Labs.** There is a critical need to develop standardized T2 documents (i. e., CRADAs) and interfaces with the DoD Lab community. There is an unnecessary burden placed upon businesses, especially small businesses when attempting to establish a business relationship with a defense laboratory. Creation of standardized documentation and uniform approaches to working with labs is essential to the expansion of Defense Laboratory T2 program.

3.3.2 DoD-Economic Impacts Review

Clarified DoD's commercialization objectives based on the DoD T2 Strategy and Plan and other industry sources. Discussed the intangible potential benefits of the T2 programs within DoD. This topic was set-up as an open, thought leader discussion..

DoD Commercialization Objectives

- Build new US industries that are competitive in the world economy
- Generate US employment opportunities, particularly those requiring skilled labor
- Foster the US innovation ecosystem
- Facilitate interagency technology transfer of complementary technologies
- Promote development of entrepreneurial US small businesses
- Promote DoD-related research at US economic institutions
- Enable the US business community to compete globally by leveraging DoD technologies

3.3.3 DoD Commercialization, Partnerships & Opportunities

Researched and discussed the legal aspects of the DoD T2 program and the implications to the Rome Lab technology space. This topic was set-up as an open, thought leader discussion.

3.3.4 Who is doing T2 well

Research and discussion were focused on T2; why DoD transfers technology determines how DoD should transfer the technology. Historical data indicates that T2 is a "lost leader" within the DoD community but has other intrinsic DoD value.

Increasing likelihood that the Tech Transfer office will be profitable:

- The larger the research budget
- The larger the tech transfer staff
- The longer the tech transfer office has been in operation

Why you transfer technology should determine HOW you transfer

- You won't become rich (Don't fall for the "lottery mentality" – but enjoy it if it occurs … or … understand mean vs median)
- Tech Transfer is really hard
  - Most universities lose money
  - Takes a long time (patience is not a government virtue)
  - Requires commercial mindset, passion, and a lot of pounding the pavement (government virtues?; charge number; incentives)
- Size matters!
  - There are significant economies of scale observed in university TTOs Could (should?) AFRL/RI take the lead for Tech Transfer for all of AFRL (AF? DoD?)…Benefits of scale, experience, and providing uniform process & procedures for interacting with commercial

3.3.5 DoD Commercialization, Partnerships & Opportunities

Research and discussion addressed the dynamics of the push pull environment where the commercial market place will pull and DoD's labs will push. Discussed the dynamic of today's threats and how T2 can be leveraged to counter those threats. This topic was set-up as an open, thought leader discussion and covered a myriad of topics.

Topics discussed:

- What are good metrics for a DoD lab?
- Quote of the day: "All successful businesses are unique, and failed businesses are alike."
- Do more patents mean more Tech Transition? Not necessarily, DoD is missing a step. Like venture capitalists, DoD needs a market survey step to determine commercialization potential.
- Discussed a centralized USAF or DoD commercialization entity to gain economies of scale.
- Discussed pros/cons of a working capital business model. Also discussed concept and benefits of co-development and connecting more directly with the users and acquisition centers.
- Discussed the threat landscape
  - We are fighting the buy-product of failed nation states (sub-state actors)
  - How do we deal with a near-peer and not get into a war?
    - Proliferation of Weapon of Mass Destruction (WMD) and the electromagnetic pulse threat
  - U.S. is not interested in a land war
  - DHS' role in 1st response
  - We will be fighting with a transient coalition
  - Threat landscape consists of contested networks (info space) and denied access
  - Discussed change detection leveraging big data analytics as tippers of maliciousness (e.g., airport elevation data)

3.3.6 Conclusions from the Topic of "Who is Doing Commercialization Well?"

- So what characteristics are shared by those Tech Transition Offices (TTOs) that are profitable:
  - TTOs > 15 years old – AND
  - Research > $500M/year – AND
  - Staffing > 20 Full Time Equivalents (FTEs)……100% of TTOs meeting these criterion were "profitable"
- Increasing likelihood that the TTO will be profitable:
  - The larger the research budget
  - The larger the tech transfer staff
  - The longer the tech transfer office has been in operation
- How successful is the DoD R&E?
  - FY2009: 690 Patent Applications
    - Assume $15K/patent then the cost ~ $10.35M/year
  - FY2009 License Income: $16.165M
    - Excluding single Army entity who made money on a single drug product, it was ~$6M
- Excluding the FTE costs – DoD is likely not even covering the cost of patents
- Submitting more patent applications without fundamentally changing the ecosystem for commercialization within DoD will only increase costs without commensurate revenue
- Commentary: Tech Transfer is a "contact sport" with required heavy lifting by the inventor (or organization) to identify potential applications, markets, and licensee
- Take a ways:
  - Why you transfer technology should determine HOW you transfer
  - You won't become rich (don't fall for the "lottery mentality" – but enjoy it if it occurs … or … understand mean vs median)
  - Tech Transfer is really hard
  - Most universities lose money
  - Takes a long time (patience is not a government virtue)
  - Requires commercial mindset, passion, and a lot of pounding the pavement (government virtues?; charge number; incentives)
  - Size matters! There are significant economies of scale observed in university TTOs

3.3.7 Conclusions from the Topic of "Federal Technology Transfer/Commercialization"

- Technology transfer to the private sector is directed in federal legislation and policy
  - Stevenson—Wydler Act of 1980 is the first in a series of laws
  - Executive Order (EO) 12591 grants private sector entities title to patents developed with federal funds
  - Air Force policy governed by AFPD 61-3 and AFI 61-301

- The Federal Laboratory Consortium (FLC) established to promote technology transfer
  - AFRL is a member of the FLC
  - *The Green Book*, published by the FLC summarizes current legislation
  - *Technology Transfer Desk Reference*, published by FLC provides process details
- All legislation and policy is consistent in language and intent
  - Improve the well-being of the U.S. … through technology transfer
  - Generally process oriented, with a focus on oversight and governance (which tends to lead toward bureaucratic implementation of standard business practices, rather than creative and innovative efforts)
  - On the commercial issue, the Government wants ease of commercial buying, but, particularly DoD, access to cost data that a commercial seller wouldn't normally release
  - Commercial companies create proprietary software so that they can make money over time, with some estimating half their revenue is via intellectual property.
    - Open architecture is designed to prevent that from happening.
  - There is private sector concern that DoD is trying in some instances to leverage industry to give up its data rights
- Some transactions were created to be non-FAR procurement contracts; however over time these implementation were written by procurement experts and now look very similar to the baseline FAR contracts.
- AFRL website and pamphlets are passive in nature
  - Promote technology transfer and provide referrals to AFIs and other sites
  - No proactive push of technology to private sector
  - Note: AFRL does participate in FLC's web-based search tool

3.3.8 Conclusions to Improve Technology Transfer or Commercialization

- Create leadership role and staff to push technology transfer: "catalyst" leader with execution and implementation focus
- Establish regular forums for making innovation and patent information available
- Reward staff member focus on the Federal objective of technology transfer: hire, train & incentivize contracting officers and patent attorneys to find ways to say "yes" as much as possible
- Consider extended internships (university, private sector) to spur innovation – NSA model is worth considering

3.3.9 Conclusions that Benefit Commercialization

- AF owning Intellectual Property (IP) provides potential to reduce life cycle costs for programs, which should provide incentives for AF (and joint acquisition programs) to fund this research
- Licensing government IP is a non-programmatic way to raise revenue for additional

research--success begets more success

- Commercialization provides a very good source of funding to attract bright science and engineering graduates to work at AF Labs
- Opportunity to develop Commercial of the shelf (COT)-equivalent for DoD vendors to incorporate in their products
- Offers a mechanism to speed acquisition by reducing or eliminating steps required for contractor risk reduction, "flyoffs," and other related DoD acquisition steps (particularly for information-related technologies that are evolving so quickly)
- Expands opportunities for DoD partnerships with academia and industry
- Offers possible mechanism to involve grad students in dual-use technologies leading to classified research—serving both as a recruiting tool and to leverage their "fresh" minds on tough DoD problems
- Offers a means to identify and develop leaders for DoD research and acquisition workforce needs
- Provides means to fund state-of-the-art research facilities for future research
- Increased commercialization, combined with proper incentives, will help with retention of key lab personnel who might be otherwise attracted by the income opportunities of the commercial sector

3.3.10 D-Wave Technical Requirement:

GTRI provided findings of a high level study on the utility to AFRL and AF of purchasing a D-Wave computer in the near term. Because effective utilization of currently deployed D-Wave computers is low, it may be more cost effective to jointly fund the purchase of a new or existing D-Wave with other interested users, and allocate some of the saved money to research on the application of D-Wave-relevant algorithms to AFRL missions. The quick look study looked as the following three high level thoughts:

- How much Global R&D dollars go into quantum computing (Asia, Europe, US)
- Technical Predictions…Oxford believes it will have a quantum computer within five years…what are other similar pronouncements? Why do they think so? What is the breakthrough?
- D-Wave. There is much debate, but could concepts and programming used on D-Wave be applied to other quantum computers (when they emerge)?

3.3.10.1 Results and Discussions D-Wave Quick Look Study:

Below, we provide findings of a high level study on the utility to AFRL and AF of purchasing a DWAVE computer in the near term. Purchase of a DWAVE computer in FY15 or FY16 is likely to result in increased attention to AFRL and AF computational problems, and increased activity by AFRL researchers in several aspects of quantum computing, but is unlikely to result in any positive warfighter impact over the next five years. Identifying AF problems that can be mapped to the computational models of DWAVE and standard quantum computers would provide valuable insight into the appropriate technical direction and mitigate AFRL risk. Because effective utilization of currently deployed DWAVE computers is low, it may be more cost effective to jointly

fund the purchase of a new or existing DWAVE with other interested users, and allocate some of the saved money to research on the application of DWAVE-relevant algorithms to AFRL missions.

Summary:

- A DWAVE computer provides no new computational ability to AFRL in the immediate future. Claims to the contrary are contradicted both by scientific literature[1] and by inspection of their customers[2],[3],[4]: Both current customers are allowing outside researchers to use the bulk of their computer time, instead of using them to solve hard computational problems that they wish to solve.
- DWAVE algorithms are significantly different from those for standard quantum computers.
  - DWAVE computers do not have the potential to solve hard factoring problems or to enable secure quantum communication, which are the most frequently cited potential benefits of quantum computers.
  - Whether a DWAVE-model computer will ever be able to outperform a classical computer in a meaningful way remains an open research question [1],[5],[6].
  - Studying DWAVE algorithms is a separate task from studying standard quantum computing algorithms, the overlap between the two is very small.
- The only class of problems shown to potentially benefit from the DWAVE computing model is quadratic unconstrained binary optimization (QUBO). Many hard problems can be mapped to QUBO problems, but no study of how these problems affect AFRL interests is known to us. Such a study is an important precursor to the purchase of a DWAVE computer.
- DWAVE computers are not helpful for building experimental expertise with quantum computing. Although DWAVE processors have some components in common with mainstream quantum computing approaches, DWAVE computers are presented as "closed boxes", making studying these components very difficult.

Current DWAVE Customers:

- **Lockheed-Martin:** Acquired a DWAVE machine, installed it at University of Southern California. Their stated goals are to use DWAVE to solve problems "from designing lifesaving new drugs to rapidly debugging millions of lines of software code". Lockheed's bigger plans for quantum research are closely held, so it is difficult to discern whether the DWAVE purchase has been successful for them. However, if it was a useful computational resource, it is unlikely that they would be allowing USC and other researchers to use it extensively, as is the case. Lockheed also has a significant standard quantum computing group, so they do not seem to believe that the DWAVE computer precludes the necessity of this research.
- **Google:** Invested in DWAVE, acquired DWAVE machine in conjunction with NASA through their "Quantum Artificial Intelligence Lab". Google hired Sergio Boixio from USC, who had been a lead in studying whether DWAVE computers provided any super-classical capabilities. Their stated goals focus on machine learning, especially for image

recognition. Google has used DWAVE heavily for public relations; it seems to be a successful way for them to showcase their research branch. No evidence that DWAVE machine has led to improved computational ability for Google yet; some evidence to the contrary:

- Google is also sharing time on the machine with outside researchers and NASA.
- Google recently acquired John Martinis's research team, who are world experts in standard quantum computing. Martinis has said that he will work toward a 40-80 qubit quantum computer at Google, which is not enough to solve meaningful QUBO problems. Although Google press releases state that Martinis will work on DWAVE-like strategies, Martinis has maintained that he intends to pursue standard quantum computing in the long term while at Google. His team, also hired by Google, includes experts in the theory of standard quantum computing; these hires indicate that Google is hedging its original bets on DWAVE technology.

3.3.10.2 Conclusions of DWAVE computer purchase (Pros):

- Purchase of DWAVE machines has drawn strong, largely-positive, public attention in the past. Purchase would demonstrate that AFRL is engaged in cutting-edge research.
- QUBO can be a large class of problems. It is possible that applications important to AFRL interests will be discovered that fit this class and can be accelerated with DWAVE.
- It may be possible to adapt core applications of current DWAVE users to AFRL applications.
- DWAVE technology may be available to adversaries. Acquisition and use by AFRL will mitigate risks for technical surprise.
- Some aspects of DWAVE computing (specifically experimental decoherence and study of super-classical algorithms) are relevant for all avenues toward quantum computing[7],[8]. Study of these particular aspects would prepare AFRL to be agile for future advances in quantum computing.

3.3.10.3 Conclusions of DWAVE computer purchase (Cons):

- The purchase of a DWAVE computer is unlikely to provide any new computational ability to AFRL in the next 5 years.
- Lab work with DWAVE does not lead directly to expertise in experimental QC (quantum computing). The DWAVE machine comes pre-packaged and does not allow testing of individual components. In the past, DWAVE has been reluctant to clearly disclose technical specifications.
- DWAVE fundamental architecture and physical basis are not like those of mainstream quantum computing or classical computing approaches. There is a strong consensus in the QC community that this strategy will not be the optimal strategy for large-scale QC and, consequently, that progress on DWAVE strategies is not progress toward large-scale QC.
- DWAVE algorithms are not like standard QC algorithms. Current research suggests that DWAVE machines' potential utility is mainly for solving QUBO (quadratic unconstrained binary optimization) problems. This problem set does not include factoring, quantum communication, or quantum simulation, which are the important

problems most commonly associated with quantum computers.

- DWAVE has taken a development and marketing approach that is frequently antagonistic to the scientific and academic communities. Support for DWAVE may discourage portions of the QC community from working with AFRL.

Reference Links: see section 4.

3.4 Results and Discussions from Meeting #3:

The primary purpose of this meeting was to conduct a walking tour of AFRL/RI's research laboratories and receive briefs from each of the divisions. The tour provided the SMEs high-level briefings, demonstrations of products/capabilities and most importantly engagement with as many of the AFRL staff as possible. The intended purpose was to provide the SMEs a deeper level of understanding and appreciation of the work being conducted at AFRL/RI in order to better enable the SMEs to provide technical recommendations. Many of the meetings were classified and no electronic products were generated.

Agenda Included:

- Stage Setting
- ATAK (Android Tactical Assault Kit)
- Distributed Common Ground System (DCGS) Modernization
- Text Analytics
- Space C2 Demo
- Special Signals Operations
- Advanced Computing
- Advanced Communication
- DHRF Tour
- Closed Door Discussions:
  - Rome-X Brief
  - NY Air National Guard/AFRL Partnership brief
  - Quantum & D-Wave Discussion
  - Internet of Things
- Discussions
- Closing Remarks

3.4.1 Conclusions for Meeting #3:

- Work will continue to refine the CONOPS and briefing on the NY ANG/AFRL partnership. Focus will be on the co-development aspects of the relationship and mission-related activities versus unit alignments. See supplemental information in section 5.6. Version 8 is the SME updates, the second document is the final version.
- Provided pros and cons of acquiring a D-Wave computer and its potential return on investment.

3.5 Results and Discussions from Meeting #4:

GTRI SMEs led discussions to address a broad set of selected topics. Each topic was review amongst the SME's via telecon prior to the meeting to focus a direction for the actual meeting. Held on 21 Aug 2015 at GTRI Washington, Rosslyn Metro Center, Arlington, VA, the primary purpose of this meeting was to discuss the Defense Innovation Unit-Experimental (DIUx) and specifically what is success, how to organize, and what it should be doing. The goal of DIUx is to meet with tech companies in search of commercial technologies that the military might find useful or commercial components to make existing military equipment better. The DIUx is part of a broader push by the Pentagon to find technologies that will give troops an edge on the battlefield of the future. The below are the fourth meeting topics:

- Defense Innovation Unit Experimental (DIUx): Described the Secretary of Defense's (SecDef) desire to take advantage of technological breakthroughs and repaid evolutions of emerging technologies. This was based on the Deputy SecDef Memorandum on the "Creation of New 'Point of Presence' Defense Innovation Unit Experimental" dated 2 Jul 15. There were three objectives identified by the SecDef:
  - Repair Relationships
  - "Gateway to infuse non-traditional ideas and talent into DoD", Capture emerging technologies (not just a widget)
  - "Point of presence," that is, act as a central hub for Silicon Valley This topic was set-up as an open, thought leader discussion.

- Silicon Valley Trip Report: In support of the DoD's DIU-X Silicon Valley office, there was a visit to over twenty start-up companies (both early and mid-stage), venture capitalists, philanthropists, and incubators & accelerators in the greater Silicon Valley area. A brief report that consolidated and anonymized key comments gleaned from these discussions was prepared but only discussed by those at this meeting. The report was funded by ASD(R&E) and not available due to sensitivities regarding this new program. This topic was set-up as an open, thought leader discussion.
- DoD-Cultural Barriers: Discussed contracting misperceptions and cultural and bureaucratic impediments to innovation. This topic was set-up as an open, thought leader discussion.
- Corporate Board Insights: Discussed the differences between the Government and Silicon Valley. This topic was set-up as an open, thought leader discussion.
- West Coast Perspective: Discussed how the Government should remain low key and how it cannot be part of the Governance process in Silicon Valley. This topic was set-up as an open, thought leader discussion.

- Chertoff Perspective: Discussed how the large companies in Silicon Valley understand that what happens in DC affects them. This topic was set-up as an open, thought leader discussion.

3.5.1 Conclusions for meeting #4:

- While the SecDef and Deputy SecDef are still in office, the DIUx must leverage the relationships to generate actionable items within Silicon Valley.
- DIUx must first understand Silicon Valley in order to understand what constitutes value within Silicon Valley.
- Leverage the positive sentiment within Silicon Valley for the warfighter's within DoD. While the Washington DC actors may not be viewed favorably, the warriors are.
- Silicon Valley technologies are based on an understanding on how to apply the technology to a valid business problem. That same problem may not have direct correlation with DoD's mission space.
- Rapid capabilities office (RCO) was stood up and staffed with a variety of functional specialists who form a collaborative melting pot of expertise. It's this intent to experiment, within the bounds of statute, to discover and recommend new methods, processes, and techniques.
- Aim to improve relationships in the Valley by providing value
  - #1 item, access to T&E resources to test their products

4 REFERENCE LINKS:

1. Recent articles refuting D-Wave's speedup claims: http://www.sciencemag.org/content/345/6195/420.abstract http://www.archduke.org/stuff/d-wave-comment-on-comparison-with-classical- computers/
2. IEEE article about Martinis and D-Wave at Google: http://spectrum.ieee.org/tech-talk/computing/hardware/googles-first-quantum-computer-will-build-on-dwaves-approach
3. Google Blog on D-Wave from last year: https://plus.google.com/+QuantumAILab/posts/DymNo8DzAYi
4. New Scientist on NASA and D-Wave: http://www.newscientist.com/article/mg22429983.300-google-and-nasa-ride-dwave-to-a-quantum-future.html?full=true#.VKGRdzDCiA
5. Letter-level description of D-Wave machine: http://www.nature.com/nature/journal/v473/n7346/full/nature10012.html
6. D-Wave paper claiming entanglement: http://journals.aps.org/prx/abstract/10.1103/PhysRevX.4.021041
7. USC paper supporting D-Wave quantum-ness: http://www.nature.com/nphys/journal/v10/n3/full/nphys2900.html
8. IBM paper refuting D-Wave quantum-ness: http://arxiv.org/abs/1401.7087
9. USC paper supporting D-Wave quantumness:http://www.nature.com/nphys/journal/v10/n3/full/nphys2900.html
10. IBM paper refuting D-Wave quantum-ness: http://arxiv.org/abs/1401.7087

5 LIST OF SYMBOLS, ABBREVIATIONS, AND SYMBOLS

A2AD	Anti-access Area Denial
AF	Air Force
AFI	Air Force Instruction
AFRL	Air Force Research Laboratory
ANG	Air national Guard
ASD(R&E)	Assistant Secretary of Defense for Research and Engineering ATAK Android Tactical Assault Kit
C2	Command & Control
C4ISR	Command & Control, Cyber, Communications, Intelligence, Surveillance & Reconnaissance
CENTCOM	Central Command
CEO	Chief Executive Officer
CIA	Central Intelligence Agency
CONOPS	Concept of Operations
COTS	Commercial of the Shelf
CTISL	Cyber Technology and Information Security Laboratory
DCGS	Distributed Common Ground System
DHS	Department of Homeland Security
DIUx	Defense Innovation Unit Experimental
DoD	Department of Defense
EO	Executive Order
FLC	Federal Laboratory Consortium
GTARC	Georgia Tech Applied Research Corporation
GTRI	Georgia Tech Research Institute
IC	Intelligence Community
IoT	Internet of Things
IP	Intellectual Property
ISR	Intelligence, Surveillance & Reconnaissance
NASA	National Aeronautics and Space Administration
NGB	National Guard Bureau
NIST	National Institute of Standards and Technology

NORTHCOM	Northern Command
NSA	National Security Agency
OSD	Office of Secretary of Defense
PACOM	Pacific Command
QC	Quantum Computing
QUBO	Quadratic Unconstrained Binary Optimization
R&D	Research and Development
R&E	Research and Engineering
RCO	Rapid Capabilities Office
S&T	Science and Technology
SME	Subject Matter Experts
SOCOM	Special Operations Command
SOW	Statement of Work
STRATCOM	Strategic Command
T2	Technology Transfer
T&E	Test and Evaluation TRANSCOMTransportation Command
TTO	Tech Transition Offices
USAF-R	United States Air Force – Retired WMD Weapon of Mass Destruction